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ORIGIN OF WEATHER TELEGRAPHY.

The great advantages to commerce, navigation, and various other public interests, of a well organised system of weather telegraphy, have now been many years in process of realisation in Europe, America, and other quarters of the globe. In the American continent, especially, the enterprise has of late been prosecuted with remarkably energy and success.

General press reports appear to have been the only sources of information in Europe regarding the impending weather, for some years previous to the time when Le Verrier began to publish the *Bulletin International.* Already, in 1854, he had urged the importance of systematic telegraphic weather reports, and, in 1855, the Emperor Napoleon sanctioned the beginning of the undertaking. The stations from which the reports were received were mostly in France; but the network was extended to foreign countries in 1857. In 1858, all the important cities of Europe were included, and on the 1st January of that year began the publication of the *Bulletin International.* Up to 1863 occasional weather warnings were issued by the French astronomer, and the importance of the matter had been frequently urged by him; but it was only in that year (obstacles having been partly removed) that the French system of daily probabilities of weather was inaugurated. In 1865, commenced the series of quarterly volumes of the *Atlas Generaux des Mouvemens de l'Atmosphere.* The storm warnings, issued since 1860, by Buys-Ballot, in the Netherlands; and those of Fitzroy and Babbington in this country, followed upon the growing success of the French system. But the recent rapid progress of practical meteorology in Europe we do not stay to particularise.

It is probably, however, to America that the earliest proposal may be traced to utilise our weather knowledge by the employment of the electric telegraph. According to Prof. Cleveland Abbe (who has written on the subject in *the American Journal of Science and Arts*), the first published suggestion appears to be that of Prof. Redfield, who, in 1846, wrote thus in the journal just named:—"In the Atlantic ports, the approach of a gale may be made known by means of the electric telegraph, which probably will soon extend from Maine to the Mississippi." The next mention of the subject is found in the *Smithsonian Report* for 1847, in an article by Prof. Loomis. "When the magnetic telegraph is extended from New York to New Orleans and St. Louis, it may be made subservient to the protection of our commerce, even in the present imperfect state of our knowledge of storms." But however frequently the suggestion may have been made, it is to Prof. Henry and his assistants in the Smithsonian Institution that Prof. Abbe assigns the credit of having first actually realised it; and the agitation of this subject in the United States, during the years 1830-1855, probably stimulated the subsequent action of European meteorologists. It is not uninteresting to trace the gradual realisation of the earlier suggestions of Redfield and Loomis, in the following extracts from the *Smithsonian Reports* of the respective years.

1847.—"The extended lines of telegraph will furnish a ready means of warning the more northern and eastern observers to be on the watch for the first appearance of an advancing storm."

1848.—"As a part of the system of meteorology, it is proposed to employ, as far as our funds will permit, the magnetic telegraph in the investigations of atmospherical phenomena. . . . . The advantage to agriculture and commerce to be derived from a knowledge of the approach of a storm by means of the telegraph, has been frequently referred to of late in the public journals; and this, we think, is a subject deserving the attention of the Government."

1849.—"Successful applications have been made to the presidents of a number of telegraph lines to allow us, at a certain period of the day, the use of the wires for the transmission of meteorological intelligence . . . as soon as they [certain instruments, &c.] are completed, the transmission of observations will commence." [It was contemplated to constitute the telegraph operators the observers].

1850.—"This map [an outline wall map] is intended to be used for presenting the successive phases of the sky over the whole country at different points of time, as far as reported."

1851.—"Since the date of the last report, the system particularly intended to investigate the nature of American storms, immediately under the care of the Institution, has been continued and improved." The system of weather reports thus inaugurated continued in regular operation till 1861, when the disturbed condition of the country rendered impossible its further continuance. . Meanwhile, however, the study of these daily morning reports had led to such a knowledge of the progress of storms, that in the Report for 1857, Prof. Henry writes:—

1857.—"We are indebted to the National Telegraph Line for a series of observations from New Orleans to New York, and as far westward as Cincinnati, which have been published in the *Evening Star* of this city. We hope, in the course of another year, to make such an arrangement with the telegraph lines as to be able to give warnings on the eastern coast of the approach of storms, since the investigations which have been made at the Institution fully indicate the fact that, as a general rule, the storms of our latitude pursue a definite course."

It would thus seem that nothing but the disturbances of the late war prevented the United States having had twelve years ago a valuable system of practical storm warnings. Even before peace had been proclaimed, Prof. Henry sought to revive the systematic daily weather reports; and, in August, 1864, at the meeting of the North American Telegraph Association a paper was presented by Prof. Baird, on behalf of the Smithsonian Institution, requesting the privilege of the use of the telegraph lines, and more especially in order to enable Prof. Henry "to resume and extend the Weather Bulletin, and to give warning of important atmospheric changes to our seaboard." In reference to this communication it was resolved: "That this Association recommend . . . . to pass free of charge . . . . brief meteorological reports . . . .

for the use and benefit of the Institution." On the communication of this generous response, preparations were at once made for the laborious undertaking, and the inauguration of the enterprise was fixed for the year 1865. In January of that year, however, occurred the disastrous fire which so seriously embarrassed the labours of the Smithsonian Institution for several following years; it became necessary to indefinitely postpone this meteorological work, which indeed had, through its whole history, been carried on with most limited financial means, and was quite dependent on the liberal co-operation of the different telegraph companies.

"It will thus be seen," writes Prof. Abbe, "that without material aid from the Government, but through the enlightened policy of the telegraph companies, and with the assistance of the munificent bequest of James Smithson, "for the increase and diffusion of knowledge," the Smithsonian Institution, first in the world, organised a comprehensive system of telegraphic meteorology; and has thus given, first to Europe and Asia, and now to the United States, that most beneficent national application of modern science, the Storm Warnings."

ON THE DISCHARGE OF ELECTRIFIED CONDUCTORS.

By M. MOUTIER.

THE electrical equilibrium at the surface of a system of conducting bodies results, as has been shown by Poisson, from the following condition:—The resultant of the actions exercised by the several electric strata upon any point taken at the interior of the conductors should be nil. If we designate by m one of these electric masses, affected by a sign according to its nature, by r its distance from a point situated at the interior of a conductor, the function—

$$V = \Sigma \frac{m}{r}$$

should then have a constant value for all points situated at the interior of the same conductor. The function V, introduced by Laplace in his *analysis*, has been designated by Green under the name of the *potential function*.

If we designate by m and m' two electro masses of the same name, situated at a distance r, each of the masses is repulsed by a force equal to $\frac{m\,m'}{r}$; if the distance of the electric masses becomes $r+dr$, the sum of the elementary works of the repulsive forces is—

$$\frac{m\,m'}{r^2}\,d\,r = -\,d\left(\frac{m\,m'}{r}\right).$$

The sum of the elementary works of all the repulsive forces is then equal to the increment of the function—

$$W = -\,\Sigma \frac{m\,m'}{r},$$

where the sum is extended to all electric masses, supposing each of them effected by a sign. The function W is designated, according to Gauss's notation, under the term of *potential of electricity*.

The labours of MM. Helmholtz and Clausius have particularly called attention to this function, which plays an important part in the phenomena of electric discharge; the increment of potential represents, in effect, the work effected in the electric discharge. M. Clausius has shown that the potential can be easily expressed by means of the charges and of the potential functions relative to each conductor; if we call V the potential upon a conductor, Q its charge,

$$W = - \quad \Sigma\, V\, Q$$

If we call V_0, Q_0 the initial values, V_I, Q_I the final values relative to a conductor—

$$W_I - W_0 = \tfrac{1}{2}\,\Sigma\, V_0\, Q_0 - \tfrac{1}{2}\,\Sigma\, V_I\, Q_I$$

measures the work effected in the partial discharge of the system of conductors, and, when the conductors are reduced to a neutral condition, the work of the complete discharge is—

$$\tfrac{1}{2}\,\Sigma\, V_0\, Q_0.$$

The mechanical equivalent of the discharge is independent of the manner in which the discharge is effected; it depends only upon the initial and final values of the potential, so that the sum of the effects of the electric discharge remain the same, whatever the nature of the discharge.

M. Helmholtz has already evaluated the momentum gained by electricity in passing from the surface of a conductor to an infinite distance; but he has considered the potential of the electricity of a conductor as a constant quantity, whilst in reality the potential diminishes upon the conductor proportionally to the charge; this diminution has for its effect the modification of the expression for the work which is produced in the discharge by air.

Let us consider an electrified conducting body having a charge q, and suppose a quantity of electricity $d\,q$ to escape from the electrified body and disappear in the air. When this electricity $d\,q$ passes from a plane surface where the potential has a value V to a plane surface infinitely near where the value of the potential function is $V + dV$, designating by $d\,n$ the infinitely small normal portion comprised between the two surfaces at the point considered, the repulsive force exercised upon $d\,q$ is $-\frac{d\,V}{d\,n}\,dq$. The elementary work of repulsion, in passing from a plane surface to a surface infinitely near, is $-\,d\,V\,d\,q$. Consequently, when the quantity of electricity $d\,q$ is extended to infinity, the corresponding work has for its value $V'd\,q$, if we term V' the potential function at the surface of the conductor, or, which is the same thing, at the interior of the conductor; this expression has already been given by M. Helmholtz.

The potential function V' is proportional to the charge q of the conductor; we can put $V' = a\,q$, a being a constant particular to the conductor. The work necessary for the infinite repulsion of the quantity of electricity $d\,q$ is $a\,q\,d\,q$. Consequently, if we term q_0 the initial charge of the conductor, the work necessary for the infinite repulsion of all the electricity of the body has for its expression—

$$T = a\int_0^{q_0} q\,d\,q = \tfrac{1}{2}\,a\,q\,{}^2_0 = \tfrac{1}{2}\,V_0\,q_0,$$

V_0 being the initial value of the potential function upon the conductor.

Also the work consumed in the infinite repulsion of all the electricity of the body is equal to the potential of the electricity, or, in other terms, the mechanical equivalent of the exterior discharge is equal to the potential of the electricity. The result is evidently the same for a system of electrified conductors.

The value of T is independent of the way in which electricity escapes from the conductors; it is easy to ascertain that this value remains the same when two equal quantities of contrary electricities recompose themselves. Let us suppose, in effect, that two quantities of electricity $+m$ and $-m$ recompose upon a point M, in order to form neutral electricity; let V be the potential function of this point. Let us suppose that, at the point M, the $+m$ electricity to be repulsed by a force $-m\frac{dV}{dn}$; the portion of the work T necessary to extend $+m$ to infinity, starting from the point M, is Vm. The quantity $-m$, on the contrary, placed at the point M, is attracted; the attractive force has the same value as the repulsive force, and when $-m$ is extended from M to infinity, the corresponding work is equal to the preceding, and of contrary sign. The value of T remains consequently the same, whether the two electricities are extended to infinity, or whether their recomposition takes place at any known point; it is necessarily the same if the recomposition is produced upon a conductor.

This is the case presented, for example, in the discharge of the Leyden jar. Let us consider a spherical bottle; let us call r the radius of the sphere which forms the interior armature, e the thickness of the glass. If we designate by q the charge of the interior armature at a given instant, by dq the quantity of electricity repulsed from the interior armature upon the exterior armature, when these two armatures are connected by a conductor, the work effected in the repulsion of the quantity of electricity dq is—

$$\int_r^{r+e} \frac{q\,dq}{r^2}\,dr = \left(\frac{1}{r} - \frac{1}{r+e}\right) q\,dq.$$

The work of repulsion which corresponds to the quantity of electricity $q_\circ$ primarily contained on the interior armature is—

$$T = \left(\frac{1}{r} - \frac{1}{r+e}\right)\int_o^{q_\circ} q\,dq =$$

$$= \tfrac{1}{2}\left(\frac{q^\circ}{r} - \frac{q_\circ}{r+e}\right) q_\circ.$$

The factor contained in the parenthesis represents the potential function of the interior armature; we find thus, in the particular case of the Leyden jar, the expression for the potential of the electricity.

We may deduce from what precedes the demonstration of a theorem established by Gauss in the case of a unique conductor, and subsequently generalised by M. Lionville for a system of conductors. When conductors enclose respectively equal quantities of the two fluids, all those conductors are in a neutral condition. In effect, in this case, the potential is nil; consequently the exterior discharge of the system of conductors cannot give place to work.

ON GALVANIC POLARISATION IN GASLESS LIQUIDS.*

By Professor **HELMHOLTZ.**

It is known that when a Daniell's element is connected with a water-decomposing cell by platinum electrodes, a current flows, which soon, however, decreases and becomes very weak, but does not quite cease, even after a long time. We may call this the *polarising* current. If the decomposition-cell is then separated from the Daniell, and its platinum electrodes are connected with a voltameter, we have another current, the *depolarising*, which is opposite in direction to the former, and, from being at first strong, soon decreases, generally, till it becomes imperceptible.

This simple experiment was my starting-point. The difficulty presented itself—Why has the polarising current an apparently unlimited duration? For in a circuit of the kind described, unless some other changes occur, the electrolytic conduction in liquids (according to Faraday's law) cannot take place without a violation of the law of conservation of force. If, that is, no other equivalents of potential energy be consumed, then the mechanical equivalent of the heat produced in the circuit must be equal to the work-equivalent of the chemical forces brought into action in electrolysis and consumed. The latter, however, is *negative* (if the decomposition take place according to the law of electrolytic equivalents), and consequently cannot be equal to a *positive* heat-work produced by the current. Decomposition of water, therefore, if Faraday's law is exclusively applicable here, cannot be continuously maintained by a Daniell, even in the smallest degree. As matter of fact, liberation of the gases forming water ceases after a time in the above experiment.

But it is not to be thought that by diffusion, or some like process, the molecules of hydrogen and oxygen, forced against the plates by the polarisation of these, becomes free again, separating in unelectric state from the plates. Such a phenomenon would ever anew give a work-result, a decomposition of water for which no equivalent acting force would be found in the Daniell. The electrical attraction of the two elements, strong enough to overcome chemical affinity, could only be overcome by a force of equal or greater equivalent of work, so as to set the attracted particles at liberty in the liquid.

If, now, the electromotive force of the Daniell, in our present case, produces no visible decomposition of water, it produces polarisation of the electrodes, and this is itself a work-equivalent. For the polarised plates are, afterwards, when separated from the Daniell, capable of giving a current which heats a conducting wire, and produces other effects of currents.

The state of polarisation is to be regarded as a new state of equilibrium to which the decomposition-cell tends, under electrification of the electrodes; and if the electricity accumulated in the electrodes can discharge itself, the cell tends to return to the state of electro-neutral equilibrium. But since, for the production of an altered equilibrium in a finite system of bodies (like the decomposition-cell), an only finite amount of work is necessary, the production of polarisation must only give a current of finite duration, or one whose intensity approaches zero asymptotically; and the polarising current can make only so much electricity flow in the one direction as the depolarising in the opposite direction.

In so far as this is the case,—and my experiments show that with gasless liquids and gasless electrodes we may come very near such a state,—the decomposition-cell acts like a condenser of very great capacity. Indeed, if we conceive, according to the usual representation, the negatively-charged hydrogen approaching to the one electrode, the positively-charged oxygen to the other, but in such a way that an exchange of electricity between the electrodes and these elements is not possible, then opposite electricity will accumulate on each electrode, which will then form with the liquid a condenser with extremely small thickness of insulating layer, and therefore of enormous capacity. This analogy has recently been pointed out by Messrs. Varley and Maxwell.

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* Abstract of a recent Paper to the Berlin Academy.

In fact, the phenomena obtained correspond, in their leading features, to those which would occur in a condenser of very great capacity. The polarising current is that which charges the condenser; the depolarising that which discharges it. We have merely to conceive the capacity of the condenser so great that its charge and discharge occupy a perceptible space of time, seconds or minutes.

The phenomena, in actual experiment with polarisable electrodes, differ from those obtained with a well-insulated conductor, in that the charging current continues much longer than the discharging, decreases more slowly, and never quite ceases. In this respect a cell with polarisable platinum plates appears to resemble a condenser with badly-insulating intermediate layer, and even the phenomena of an electric residuum have their analogies in the increase of the polarisation after each interruption of the current.

It seemed reasonable to assume the same cause, in a decomposition-cell, for the continuance of the charging current as in a badly-insulating condenser, viz., the existence of a slight conductivity like that of metals in electrolisable liquids, which would limit the applicability of Faraday's law. Before we adopt this conclusion, however, we should inquire whether there may not be other changes in the liquids and the electrodes which might give a like result. And it is of primary importance to consider the influence of gases, dissolved in the liquid, or (according to Graham's discovery), occluded in the metal of the electrodes.

It is known that the galvanic polarisation of a platinum plate which serves as hydrogen-electrode in a decomposition-cell may be diminished or stopped by direct contact with the oxygen of the air, by addition of aërated water, or by contact of liquids with which oxygen is chemically bound. The same thing holds for the oxygen-polarisation of a platinum plate when it is in contact with hydrogen dissolved in water, or with other compounds which can take up oxygen.

We further know, from Graham's experiments, that platinum has the power of absorbing hydrogen into its mass. And it appears to be similarly capable of absorbing oxygen, though in much less degree. If, now, an electric current pass through a decomposition-cell, the liquid of which has hydrogen dissolved in it, or the electrodes of which have occluded hydrogen, the oxygen, separated by the current, and driven towards one of the electrodes, will be able to unite with the dissolved hydrogen, or the occluded hydrogen, again forming water. On the other hand, in place of this hitherto free hydrogen (free at least from union with oxygen), an equal quantity of electrolytically separated hydrogen will again appear at the other electrode, and either become dissolved in the liquid, or (if time and space are given), be forced into the platinum electrode itself. Although, then, electrolysis occurs in the liquid, the two products of electrolysis do not, ultimately, appear; the final result being that free hydrogen disappears at or in the one electrode, and appears at or in the other in greater quantity. I propose to give this phenomenon, which plays an important part in polarising currents, the name of *electrolytic convection*. It can be maintained in a liquid by a weak electromotive force, which is not capable of actually decomposing water, as, *e.g.*, the force of a Daniell element; the work is not directed to the forces of chemical affinity of oxygen and hydrogen.

A similar thing occurs when the liquid contains oxygen, or the platinum plates have occluded oxygen. Then free oxygen disappears by electrolytic convection at the one side, while an equal quantity appears at the other. The hydrogen or oxygen, thus become free at one electrode by convection, is (so far as it is not occluded in the electrode) as free to diffuse in the liquid, to be carried away by currents in this, to develop as gas if the liquid is saturated, as the gas developed in ordinary electrolysis. As it is diffused in the liquid, it will again reach the other electrode to again undergo electrolytic convection, and in this way maintain a certain strength of continuous current.

A Daniell element may thus maintain a continuous weak current in a water decomposition-cell with platinum electrodes, not merely when the liquid is in contact with air, but also in a perfectly closed vessel, if the electrodes are saturated with oxygen, and the liquid has oxygen dissolved in it.

The apparatus with which I experimented in this direction was a hermetically closed voltameter connected with a mercury air-pump, and containing two large cylindrical platinum plates bent together, having a surface of 180 to 300 square centimetres. The liquid in this voltameter reached, below, to the mercury of the pump, with which it rose and fell, while the gases, collecting over the liquid, could be removed by a peculiar stopcock. It was thus possible to produce over the liquid a vacuum containing only hydrogen vapour, and to free the liquid gradually from every trace of dissolved gas.

The plates could be saturated with oxygen by placing them together, for some days, as one electrode of a weak current at which oxygen was developed. I have observed a current maintained for a week by electrolytic convection, under the influence of a limited supply of oxygen in hermetically enclosed liquid. It is characteristic of the influence of the liquid that any mechanical movements in it, but especially circulating movements produced by changes of temperature, give a marked increase of current. This is almost entirely absent in gasless liquids.

Hydrogen, however, is much more active in the above-mentioned relation than oxygen, because it can accumulate in very large quantity in the plates. The plates and liquid being fully saturated with electrolytically-developed hydrogen, such a decomposition-cell will behave towards weak currents, for hours, and even a whole day, as an unpolarisable element, similarly to a silver solution between silver electrodes. One may take measures of resistance in the circuit with the greatest accuracy, and it shows, after breaking the battery current, hardly a trace of polarisation. The constancy of the current ceases, however, when, through the convection of hydrogen, the supply of this in one plate begins to be small.

Under such conditions, we may, with only one (but a good conducting) Daniell element, sometimes observe development of hydrogen as gas at the plate to which it is brought; that is, a merely apparent decomposition of water. That this occurs has been remarked by previous observers, but without specification of the conditions.

The phenomena are but slightly different when, without changing the conditions of the electrodes, the electrolytic liquid is made quite gasless, through action of the mercury pump for some weeks. Even in this case, if the plates were originally charged with one of the two gases, currents appeared, which might last several days, but which ultimately sank so low as to be no longer perceptible. The multiplier here used gave some deflection when a current passed through it which was capable of developing 0·03 c.c. hydrogen in 24 hours. A second difference is, as already remarked, that there was no strengthening of the current or movement in the liquid.

The influence of gas occluded in the platinum plates, in this case, appeared very distinctly, when I altered the quantity of gas. With this end I brought small quantities of hydrogen electrolytically to plates which were first charged with oxygen, the second electrode being mercury mixed with a little zinc, and the electrolytic liquid distilled water. The oftener this was done, the shorter were both the current produced by a Daniell element in the voltameter, and the depolarising current after shutting off the Daniell. The same stages of current strength which at first were passed in 24 hours, when the plates were richly charged with oxygen, were ultimately passed in 18 minutes, the plates being as clean as possible. If, however, I then added hydrogen to the plates, the duration of current rose again, because of the hydrogen charge. I do not think that I reached the minimum gas charge in the plates; it is a very tedious operation, because the gases in metal move forwards very slowly when they are not driven by an electromotive force. To expel the last remains thus takes a long time.

The phenomena which, in polarisation, are similar to those of the residuum in a Leyden jar, are explained by the occlusion of gases. When hydrogen is attracted to a platinum plate, and the current is broken for some seconds, the gas has time, during this interruption, to penetrate further into the interior, and thus to become of less density in the superficial layer. If the circuit be again closed, the resistance to penetration of fresh hydrogen will be less, and the current will be stronger. Conversely, the depolarising current removes the gas driven out to the surface; if the current is broken, the hydrogen slowly driven forward from within accumulates at the surface and increases its polarisation. It is known that behind an oxygen polarisation in a platinum plate there may exist, simultaneously, an older hydrogen polarisation, which latter comes to view when the first disappears, and *vice versâ*.

So far as I see, phenomena of this class may be explained without difficulty if we accept the same laws for propagation of gases occluded in metals as for conduction of heat.

Lastly, it is to be remarked that in this case, after the condensing current has passed, that is, after the quantities of electricity held at the surface of the plates have been discharged, a further current can only occur as more gas passes from the interior to the surface. If this takes place very slowly, the strength of current in the circuit will be as good as independent of its resistance, so that in my experiments, while the insertion of 20 to 60 miles of telegraph wire made the needle of the multiplier move back for several seconds, it soon again allowed the previous deflection.

MATHEMATICS
FOR
NON-MATHEMATICIANS.

By T. C. SIMMONS, B.A. Cantab.

Simple Equations.

The reader has now become acquainted with most of the processes which in algebra correspond to similar processes in arithmetic. He is now able to add, subtract, multiply, and divide: he knows how to use logarithms, and has been shown how to sum arithmetical and geometrical series. I propose to lead him into a new part of algebra, which is extensively used in all the applications of mathematics to physical science. To make it as clear as possible, I shall begin with some definitions and statements which he will readily admit; and shall then, as well as I can, deduce from them results, and so gradually he will become familiar with the subject. To begin, then, with a few definitions.

(1.) An equation expresses the fact that one algebraical quantity is equal to another. Thus, when we make the statement that a quantity which we call x is equal to another quantity which we call a, we express it in this form—

$$x=a$$

and this is called an *equation*. Suppose, however, we wish to state the fact that if the square of a number together, say, with three times that number, is equal to four (any other number would do equally well), we should express it as follows—

$$x^2+3x=4$$

This is an equation a little more complex than the other, and is called by a different name. I shall consequently now add other definitions.

(2.) When the equation only contains the first power of x, it is called a *simple equation*.

(3.) When it contains the square of x, and no higher power, it is called a *quadratic equation*.

Thus the first of the above equations is called a simple equation, the second a quadratic equation.

Similarly, if the equation contains the third power of x, or x^3, and no higher power, it is called a *cubic equation:* if it contains x^4 and no higher power, it is called a *biquadratic equation*, and so on. We need not, however, for our present purpose consider anything higher than quadratic equations. To begin, then, with simple equations.

Suppose we have to determine or find the value of x (in equations x is generally used to denote the quantity whose value we wish to find), and that we have given the equation—

$$x+a=b$$

Now if two things be equal, and we add the same to both, we know that they will still be equal. For instance, if two vessels contain equal quantities of water, and we add to each vessel one pint of water, the quantities of water contained in the vessels will still be equal. In the same way, if we take a pint of water from each, the quantities in the two vessels will still be equal. Now in the equation—

$$x+a=b$$

subtract a from both sides, then the remainders will be equal, or—

$$x=b-a$$

Thus we see that the quantity a is transferred from one side of the equation to the other, with its sign changed. The same thing will always hold, as the reader will see without difficulty, if he considers every case separately. He will see that if—

$$x+a-b=c-d$$

then—

$$x+a=c-d+b$$

or—

$$x+a-b-c=-d$$

or—

$$x+a+d=c+b$$

or—

$$x-b=c-d-a$$

Again, it is not difficult to see that if we multiply or divide both sides of an equation by the same quantity, the equation will still be true. To go back to our old illustration of the vessels of water, it is easy to see that if the quantities of water in the two vessels are equal, and we add water to each, so that each contains twice as much water as it did before, the quantities will still be equal. Similarly, if we take water out, and leave in each vessel only one-half or one-quarter of that which was there before, there will still be equal quantities of water in each vessel. Thus, to put the fact in algebraical language, if $x=a$ be an equation connecting x with the known quantity a, then will—

$$nx=na, \text{ and } \frac{x}{n}=\frac{a}{n}$$

where n is any number whatever.

Suppose, now, that the unknown quantity, called x, satisfies the following equation—

$$3x+5=2x+8$$

and we require the value of x. To find it, transfer $2x$ with its sign changed to the left-hand side, and 5 with its sign changed to the right-hand side; we then get—

$$3x-2x=8-5$$

or—

$$x=3$$

Thus the value of x is 3 in this case. When we have reduced an equation to such a form that the unknown quantity stands by itself on the left-hand side, without any multiplier or divisor, and known quantities on the right-hand side, we are said to have *solved* the equation; and the expression of the fact that x is equal to a quantity which is known, is called the *solution* of the equation. Thus—

$$x=3$$

is the solution of—

$$3x+5=2x+8$$

Again, suppose we require the solution of—

$$5x+9=6x+3$$

Proceeding as before, that is, putting all the terms containing x on the left-hand side, and all the known quantities on the right-hand side, we get—

$$5x-6x=3-9$$

or—

$$-x=-6$$

Change the sign of both members*, and we obtain—

$$x=6$$

which is the required solution. The reader will observe that in the above example the signs of both members are changed in order to obtain the solution. This is necessary, as we require the value of $+x$, and not of $-x$. A reason may be given why this is permissible, in this way:—Suppose $-x=-6$, then we can transfer each member to the other side, if we alter its sign: thus we get $6=x$. But if we say that 6 is equal to x, it is just the same as saying that x is equal to 6.

Thus $x=6$.

If the reader does not quite understand this, I would advise him not to trouble about it. as he will see it more clearly when he has made more progress in mathematics, and has become familiar with the relation which positive and negative numbers bear to one another. He may at present take it for granted.

Again, suppose we have to solve—

$$4x+\tfrac{3}{4}x=2x+11$$

Then—

$$4.x+\tfrac{3}{4}.x-2.x=11,$$

the dot signifying that the two quantities between which it stands are to be multiplied together (thus $4.x$ stands for $4\times x$).

or—

$$(4+\tfrac{3}{4}-2)x=11$$

or—

$$2\tfrac{3}{4}x=11$$

or—

$$\frac{11}{4}x=11$$

Divide each side by 11, I have shown that this can be done, and we get—

$$\tfrac{1}{4}x=1$$

Multiply each side by 4, thus—

$$x=4$$

A more usual way of proceeding, however, is as follows: at the very beginning of the process multiply both members, each by the same number, so that the fractions disappear.

Proceeding thus, the equation—

$$4x+\tfrac{3}{4}x=2x+11$$

becomes, if we multiply by 4—

$$16x+3x=8x+44$$

or—

$$11x=44$$

or—

$$x=4$$

The reader can in any particular case apply either method: he can retain the fractions if he pleases, or can get rid of them: he must bear in mind that whatever he does to one member (whether he add to it, or subtract from it, or multiply, or divide), he must do the same thing to the other member, always: if he constantly remembers this, he will not easily get wrong. Again suppose—

$$ax+b=cx+d$$

In any equation like the above, where the letters a, b, c, &c., occur, their values are always supposed to be known; x being the only unknown quantity. Proceeding as before, we have—

$$ax-cx=d-b$$

---

* The two parts of an equation, separated by the symbol = are called its *members*.

or—

$$(a-c)x=d-b$$

or—

$$x=\frac{d-b}{a-c}$$

which is the solution, since a, b, c, d, are supposed to be known.

I shall now give rules for solving simple equations.

(1.) Bring all the terms containing x on the left-hand side, and all the other terms on the other side: bearing in mind that the sign of any term must be changed when it is taken from one side to the other.

(2.) If there be fractions, it will generally be convenient (but not necessary) to multiply both members by such a quantity as to make the fractions disappear.

(3.) Reduce the equation so that $+x$ occurs on the left-hand side, and known quantities on the right: then the equation is solved.

I shall now give some examples, which I recommend the reader to work out by himself, and then compare his solution with mine:—

(1).
$$2x+\frac{x}{6}+\frac{3x}{4}=8,$$

Multiply by 12.

Then
$$\begin{aligned}24x+2x+9x&=96\\35x&=96\\x&=\frac{96}{35}\end{aligned}$$

(2).
$$\begin{aligned}\frac{3x}{a}+\frac{1}{b}&=\frac{2x}{a}+\frac{4}{b}\\\frac{3x}{a}-\frac{2x}{a}&=\frac{4}{b}-\frac{1}{b}\\\frac{x}{a}&=\frac{3}{b}\\x&=\frac{3a}{b}\end{aligned}$$

Or, we may proceed thus—

$$\frac{3x}{a}+\frac{1}{b}=\frac{2x}{a}+\frac{4}{b}$$

Multiply by ab, so as to make the fractions disappear, then—

$$3bx+a=2bx+4a,$$

or—

$$\begin{aligned}3bx-2bx&=4a-a\\bx&=3a\\x&=\frac{3a}{b}\end{aligned}$$

the same as before.

(3).
$$\tfrac{2}{3}x+\tfrac{7}{9}x=x+\tfrac{4}{9}.$$

Multiply by 9.

Then
$$\begin{aligned}6x+7x&=9x+4\\4x&=4\\x&=1\end{aligned}$$

(4).
$$\begin{aligned}ax-a^2&=bx-b^2\\ax-bx&=a^2-b^2\\(a-b)x&=a^2-b^2\\x&=\frac{a^2-b^2}{a-b}\end{aligned}$$

Now, if the reader multiplies $a+b$ and $a-b$ together, he will find the product is a^2-b^2.

$$\text{Thus } a^2-b^2=(a+b)(a-b)$$

$$\begin{aligned}\text{and } x&=\frac{(a+b)(a-b)}{a-b}\\&=a+b\end{aligned}$$

since in a fraction we can divide both numerator and denominator by the same quantity without altering its value.

(5).
$$\begin{aligned}\log.\ x+\log.\ (x^2)&=3\log.\ a\\\log.\ x+2\log.\ x&=3\log.\ a\\3\log.\ x&=3\log.\ a\\\log.\ x&=\log.\ a\end{aligned}$$

But if the logarithms of two numbers are equal, the numbers themselves are equal, so that $x=a$, which is the solution.

(6).
$$a^x=c+d.$$

Take the logarithms of both sides.

$$\begin{aligned}\text{Then }\log.\ (a^x)&=\log.\ (c+d)\\\text{or } x\log.\ a&=\log.\ (c+d)\\x&=\frac{\log.\ (c+d)}{\log.\ a}\end{aligned}$$

If the logarithms be taken with regard to the base a, then $\log.\ a=1$, as was proved in a previous paper,* and we have—

$$x=\log._a(c+d).$$

Thus x is the logarithm of $c+d$ to the base a. We need not, however, have worked out this case, as from definition, if $a^x=c+d$, x is the logarithm of $c+d$ to the base a.*

I may here perhaps caution the reader against a possible error; he may be, perhaps, inclined to proceed thus—

$$a^x=c+d$$

$$\begin{aligned}\text{Then }\log.\ (a^x)&=\log.\ c+\log.\ d\\&=\log.\ cd\end{aligned}$$

which is altogether wrong. He should always consider what he is doing, and should reason in this way:—"If two numbers are equal, so are their logarithms, so that if $a^x=c+d$, then—

$$\log.\ (a^x)=\log.\ (c+d)\text{"}$$

and not merely say "take logarithms." He must remember that he must always take the logarithm of the *whole* member, and not of parts of it separately. I have introduced the last two examples as exercises in logarithms. If the student finds them too difficult, he should reserve them for future consideration. I add a few, which I hope he will try to work out for himself—

(9).
$$32x+a+\frac{x}{3}=c+\frac{100x}{3}$$
Sol. $x=a-c$

(10).
$$3x+2x+5=40-2x$$
Sol. $x=5$

(11).
$$51-4x=13x$$
Sol. $x=3$

(12).
$$39+3x=1-16x$$
Sol. $x=-2$

(13).
$$a^{x-c}=d$$
Sol. $x=c+\dfrac{\log.\ d}{\log.\ a}$

In my next paper I propose to lead the student to quadratic equations, showing him how to solve very easy ones; and shall afterwards, as soon as possible, accompany him into the more elementary portions of trigonometry, with which it will be necessary that he should be acquainted.

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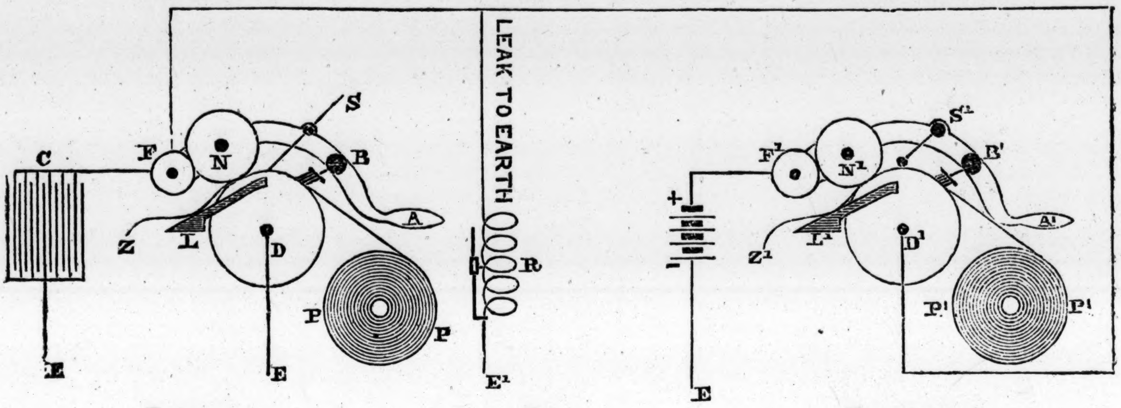
* See Dr. Higgs's article, vol. i., p. 221.

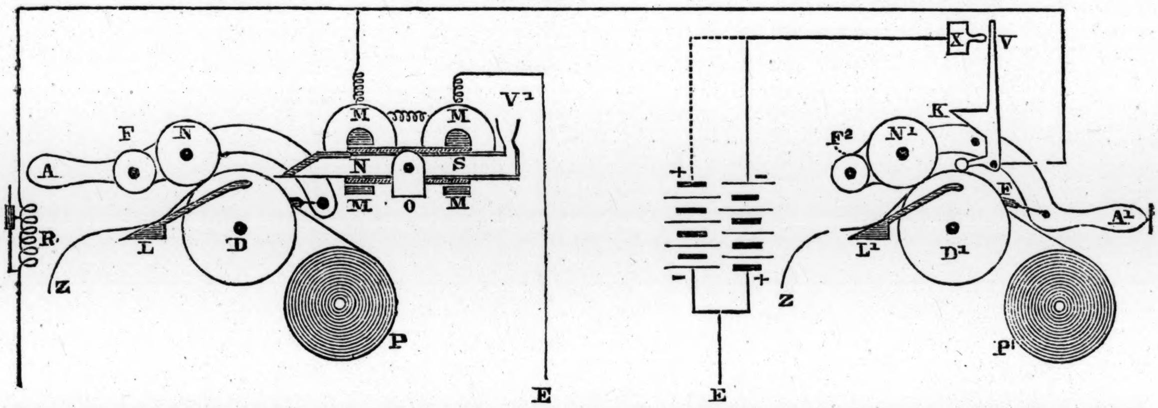
LITTLE'S RAPID AUTOMATIC TELEGRAPH SYSTEM.

THE devices employed in this system are, as will be seen by reference to the diagrams, classed under two heads—a chemical writer, which is involved in a system of the first order, and an ink writer, in a system of the second order.

RECEIVER. FIG. I. TRANSMITTER.

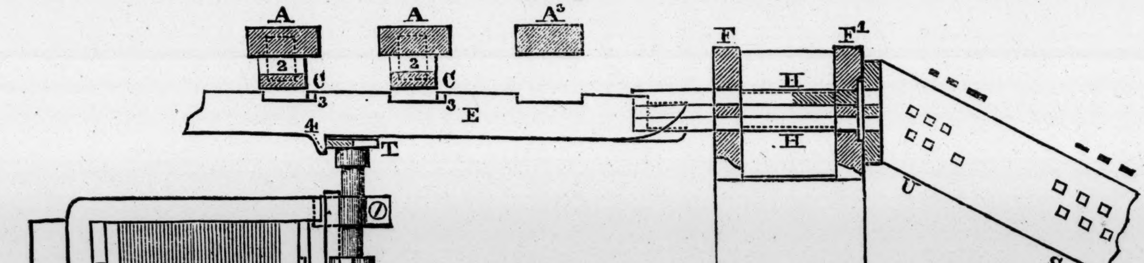


RECEIVER. FIG. 2. TRANSMITTER.



It should be stated that any number of the Little automatic apparatus may be run, all at varying speeds, on the same circuit, without in the least interfering with the legibility of the writing, as the characters on each receiving instrument assume their own relative proportions with mathematical accuracy.

FIG. 3.



The Automatic Telegraph Company, of which the Hon. George Harrington is President, have now this system in operation, by virtue of an agreement with Mr. Little, between the United States Capitol at Washington, D.C., and some of the most important commercial cities in the country.

In the chemical writer (Fig. I) D D^I are flanged drums, which may be set in motion by any of the well-known devices, but preferably by a small belt leading to a crank-handle, to be worked by hand power, the labour required being very slight. P P is a roll of chemically-prepared paper; P^I P^I a roll of paper having telegraphic symbols, perforated or embossed on the same. The end of each roll of paper, Z Z^I, is passed over the drums, and held in firm contact with their surfaces by the nipping rollers N N^1, and brushes or detainers B B^1, upon the arms or levers A A^1, which are secured or swung upon the fulcrums F F^1, and held down by a tumbler spring. The stylus, S, is composed of a metal, the nature of which depends mainly upon the formula of the chemical solution employed, and through which the prepared paper may have been passed. S^1 is the transmitting rollers; L L^1 the lifting blades, lying in a groove sunk in each of the drums, and whose province it is to prevent over-winding and breaking the paper. It should be observed that N S B are secured to one arm, A, so as to facilitate handling of the apparatus. $+ -$ is the battery, one pole of which is put to the earth, E R is an adjustable, or a series of adjusted rheostats, as used with Gintl's duplex, 1853-4, connected in a branch line or in a shunt circuit, in order to leak the surplus current to earth. C may be any suitable condenser used for the purpose of absorbing extra current, also connected to earth or in a shunt. For convenience, the wire E^2, leading to drum D, may be connected, so that all three wires, E^1 E^2 E^1, may be united to one earth connection. The relay sounder, polarised relay, or the direct sounder used in connection with this system, to give the signals "Go ahead," "Stop," &c., is not necessarily shown in the diagram.

In the ink writer (Fig. 2) it will be seen that there are two batteries with $+ -$ and $- +$ poles, the positive pole of one being, with the negative pole of the other, connected to earth at E. The opposite poles are connected separately to two adjusting contact screws at X—one only of which is shown in the diagram, the other being behind, and consequently not visible. V is one of two vibrating levers, mounted or swung on one common jointed fulcrum, F^1. The controlling discs, as will be seen, are mounted on the short end of the lever over the drum D^1. The angular or wedge-shaped portion of the lever V at K is so situated as to allow the pin seen below and secured to the arm A^1 to simultaneously lift the levers, with their controlling discs, clear of the perforated or embossed paper, P.

It will be seen that when in action an alternate rise and fall of each of the short arms of the lever V, during the passing of the telegraphic symbols between the same and the drum D^1, will cause an enlarged motion of the longer ends at V, and thus cause alternate contacts with the batteries to be made at X, consequently passing alternate or reversed currents of equal strength, and, as near as possible, of equal duration, along the main line, so as to bring into action the pen, seen passed through the hollow permanently polarised armature, swinging or mounted on its fulcrum O, with its poles, N S, which is caused to vibrate between the poles of the electro-magnet M M M M, having its coils, as seen, to the main line and earth at E.

The electro-magnets and pen-nibs are adjusted jointly to or from the dry paper, P, as the same passes over the drum D, by a rack and pinion at the back of the magnet. The rheostat R passes off to the earth at E any excess of current.

The pen is kept constantly supplied, by means of the funnel V^1, with a peculiar cheap readily-flowing ink, from a flexible rubber syringe. The peculiar ink used does not dry or corrode on the pen-nibs.

When this ink writer is arranged to operate with a direct current, and with the use of a retractile force, a condenser may be applied to each side of the magnet, or in a branch circuit to earth.

The chief feature of the perforator, shown in Fig. 3, is that it relieves the hand of the operator from the jar and strain to which the same is subjected if the punches are projected by power directly applied by the fingers or hand to the keys.

In the perforator, as shown, two electro-magnets are employed:—One to select and project the required number of punches to perforate or emboss the symbols in or on the paper. This magnet is not shown in the diagram, it being placed behind the magnet M. The magnet M is used as being preferable to springs, for the purpose of withdrawing the punches suddenly from the paper and returning the same to their normal position. The finger keys, A A A^2, three of which are shown in the diagram, are of any desired number, according to the number of characters required to be perforated. These keys are placed side by side, and are hinged to a horizontal bar, and on the underside of each key, levers, C C, are pivoted at 22. Beneath the finger-keys are the requisite number of slides, E, to which the punches H H are secured, which pass through the heads F to F^1, to which is secured the *die*, between which and F^1 the paper to be perforated or embossed passes or is drawn by the depressed finger-key, acting upon pins on a rock shaft, from which shaft motion is communicated to a drum over which the paper is drawn a proper distance, after which the electric contact is made, so as to complete the circuit with a battery or other source of electric power, as, for instance, a *gramme* apparatus, in order to project the punches. On letting up the key, contact is made and the circuit completed with the magnet M, which attracts the armature S, which swings the cam T against the projections, four of the sliding bars, E, thereby suddenly withdrawing the punch or punches from the paper, U, S.

The characters composing the message to be transmitted, having been perforated upon the paper used for that purpose, the end of the strip is passed over the drum of the transmitter, as shown in Fig. 2, and by means of the crank this drum is rotated at any desired speed. As the embossed or perforated symbols pass the circuit is closed, and the symbols transmitted to the receiving instrument. At the same time the chemically-prepared paper, or the paper upon which the symbols are to be imprinted by the ink writer, is simultaneously drawn over the drum of the receiving instrument, and the symbols are impressed upon it with unerring accuracy. These strips, thus impressed, are taken by expert clerks, and translated into ordinary characters, and written or printed upon the usual blanks for delivery to the persons for whom they were intended.

THE report of the Eastern Telegraph Company (Limited), presented on the 27th ult., states that the Directors have concluded a joint-purse traffic arrangement with the Indo-European Telegraph Company. The net revenue for the six months ended the 30th of September amounted to £122,826, and an interim dividend of 1½ per cent. on the 14th of October and a further interim dividend of 1¼ per cent. declared on the 7th inst., amounting together, with interest on new shares, to £99,932, leaves a balance of £22,893 to be carried forward.

Students' Column.

Resistances and their Measurement.—By H. R. Kempe.

V.—To obtain the most accurate results in measuring resistances with the tangent galvanometer, it is best so to adjust our resistances or battery-power as to obtain deflections ranging between 30° and 50°, which range is sufficient for most measurements. Deflections above or below these values should be avoided if possible.

The reason for avoiding deflections below 30° is because a small error made in reading off the deflections from the scale will produce a large error when a result is worked out from a formula in which these deflections enter. And, on the other hand, if we take readings above 50°, a large alteration in our resistances will produce but little effect on the galvanometer needle, as the instrument is not as sensitive with high as with low deflections.

That these sources of error exist will perhaps be best shown by examples.

Thus, in taking the formula given on page 9, viz.:—

$$R = \frac{\alpha_1^\circ}{\alpha^\circ}(\rho + G) - G,$$

or, as it would be more correctly written—

$$R = \frac{\tan \alpha_1^\circ}{\tan \alpha^\circ}(\rho + G) - G,$$

taking $\rho = 200$ ohms and $G = 100$ ohms, supposing we had obtained the deflections $\alpha_1^\circ = 15^\circ$ and $\alpha^\circ = 10^\circ$, we should have—

$$R = \frac{\tan 15^\circ}{\tan 10^\circ}(200 + 100) - 100 = 354{\cdot}84 \text{ ohms}.$$

Now suppose, owing to the unsteadiness of the needle, or some other cause, we had read the deflection 15° as 16°, that is, one degree more than it should be, by inserting this value in the formula in the place of 15°, we should get—

$$R = 387{\cdot}88 \text{ ohms},$$

which gives $387{\cdot}88 - 354{\cdot}84 = 33{\cdot}04$, or 11·75 per cent above the true value of R.

If now, in measuring a resistance, instead of 15° and 10°, we had obtained, by using higher battery-power, deflections of, say 42° and 31°, we should have—

$$R = \frac{\tan 42^\circ}{\tan 31^\circ}(200 + 100) - 100 = 349{\cdot}56 \text{ ohms}.$$

And supposing, as before, that we had read one degree too much, that is, 42° as 43°, then—

$$R = 365{\cdot}58.$$

which gives $365{\cdot}58 - 349{\cdot}56 = 16{\cdot}02$, or an error of 4·58 per cent only as against 11·75 per cent in the last case.

This, then, shows the advantage of taking readings above 30°. We have next to show that the error caused by taking readings above 50° is also a large one.

Supposing, with the before-mentioned resistances, we had obtained deflections of 75° and 68°. We should get, by insertion in the formula,

$$R = 352{\cdot}36.$$

and if deflection 75° was read, in error, as 76°, then—

$$R = 386{\cdot}15.$$

which gives $386{\cdot}15 - 352{\cdot}36 = 34{\cdot}79$, or 12·43 per cent above the true value of R, an error as large as the one we had when the readings were taken below 30°.

We will now consider some of the more elaborate measurements which can be made with the tangent galvanometer and resistance coils.

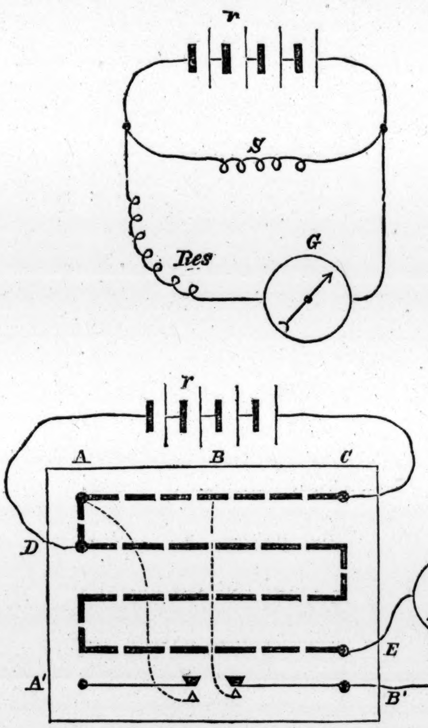
First.—To determine the internal resistance of a Battery.

First method.—On page 9, we gave a formula for determining the resistance, r, of a battery, viz.:—

$$r = R - (2\rho + G).$$

where G was the resistance of the galvanometer used, R a resistance which gave a certain deflection on the tangent scale, and ρ a smaller resistance which gave double that deflection. The formula may perhaps be rendered clearer by expressing it in words, thus:—Join up a resistance box (as the set of resistance-coils is frequently termed) a tangent galvanometer, and the battery whose resistance is required in simple circuit. Adjust the resistance-coils until we get, say 35 divisions (about 32°) deflection on the *tangent* scale of the galvanometer.

Fig. 7.



Note the resistance (R) in the resistance box. Now decrease the resistance until the deflection on the tangent scale becomes 70 (about 50°), that is to say, twice 35. Again note the resistance (ρ) in the box. Then, to get the resistance of the battery:—*Double the smaller resistance; to the result add the resistance of the galvanometer, and deduct this total from the greater resistance.*

Example.—With a tangent galvanometer whose resistance (G) is 100 ohms, and a battery whose resistance (r) is to be determined, we obtained with a resistance (ρ) in the resistance box of 150 ohms a deflection of 40 divisions on the tangent scale, and on increasing ρ to 600 ohms (R), we obtained a deflection of 20 divisions. Then resistance of battery is—

$$r = 600 - (2 \times 150 + 100) = 200 \text{ ohms}.$$

Second Method.—Join up the resistance box, galvanometer, and battery, as shown in Fig. 7. In this figure the upper cut shows the theoretical method of joining up, and the lower one the practical method. If we were working with the set of coils shown in Fig. 4, the terminal of the galvanometer joined to B′ would be instead joined to C. We can, of course, adopt the same arrangement in the set of coils shown in Fig. 7, but then we should lose the advantage of having the key in circuit which enables us to cut off the current when we please. The theory of this method of measurement is as follows:—The galvanometer, a resistance box (Res.), and battery whose resistance (r) is required, are joined up in simple circuit with a shunt resistance (as it is called) S, between the poles of the battery; a deflection of the galvanometer needle is produced with a resistance ρ in the resistance-box. Let E be the electromotive force of the battery, and I the intensity of the current passing out of it, then—

$$I = \frac{E}{r + \frac{S(\rho+G)}{S+(\rho+G)}}.$$

This current splits up in two parts, one part going through S, and the other part through the resistance-box and the galvanometer; it does this in the inverse proportion of the resistances of those circuits. The part going through the galvanometer being—

$$I' = \frac{E}{r + \frac{S(\rho+G)}{S+(\rho+G)}} \times \frac{S}{S+(\rho+G)}$$

$$= \frac{ES}{r(S+\rho+G)+S(\rho+G)}.$$

The shunt S is now removed; this causes the deflection of the galvanometer needle to be increased. ρ is now increased to R until the deflection becomes the same as it was previous to the removal of the shunt, or, in other words, until the intensity of the current passing through the galvanometer is I′. Then—

$$I' = \frac{E}{r+R+G},$$

whence—

$$\frac{E}{r+R+G} = \frac{ES}{r(S+\rho+G)+S(\rho+G)}$$

By multiplying up and cancelling—

$$r(\rho+G) = S(R-\rho),$$

or—

$$r = S\frac{R-\rho}{\rho+G}.$$

This method was devised by Sir William Thomson.

Example.—With a galvanometer whose resistance (G) is 100 ohms, and a battery whose resistance (r) is to be determined, we obtained with a resistance (ρ) in the resistance-box of 500 ohms and a shunt whose resistance is 1000 ohms a deflection of 30°. On removing the shunt it was necessary, in order to again bring the needle to 30°, to increase ρ to 620 ohms (R). Then resistance of battery is—

$$r = 1000\,\frac{620-500}{500+100} = 200 \text{ ohms}.$$

This calculation may be considerably simplified if we adjust ρ, in the first place, so that together with G it equals S, for then we get—

$$r = S\frac{R-\rho}{S} = R-\rho,$$

that is to say, the resistance of the battery is equal to the resistance which was added to ρ in order to make the deflection of the needle the same as it was previous to the removal of the shunt.

Example.—With a galvanometer whose resistance (G) is 100 ohms, and a battery whose resistance (r) is to be determined, we obtained a deflection of 25°, using a resistance ρ of 200 ohms, which, together with the resistance of the galvanometer, made a total resistance equal in value to that of the shunt, viz., 1000 ohms. On removing the shunt, it was found necessary, in order to again bring the needle to 25°, to increase ρ to 1100 ohms (R), that is, to add 200 ohms to it, which is therefore the resistance of the battery.

In making this test practically, we should thus proceed:—Join up the instruments, as shown in Fig. 7, taking care that the two infinity plugs are firmly in their places. Plug up the three holes between B and C, and remove the necessary plugs between A and B. As there are only three plugs here, our choice of a resistance is limited to 1000, 100, or 10, but these are, as a rule, sufficient for all purposes. Now depress the right-hand key, and proceed to remove plugs from between D and E until a convenient deflection of the galvanometer needle is obtained. The galvanometer should be gently tapped with the finger in order to see that the needle is properly deflected and is not sticking, as it is very liable to do, especially when a compass suspended needle is used. The oscillations of the needle may be arrested by a skilful manipulation of the key, easily attained by practice, the key being slightly raised when the needle swings under the influence of the current and again depressed when it recoils. The needle being steadily deflected, and the resistance in the box noted, the left hand infinity plug is removed, and the resistance between D and E increased until the deflection becomes the same as at first, and the resistance being noted, the formula is worked out. When adopting the simplified method, the resistance between D and E would be adjusted in the first place previous to the depression of the key. To obtain accurate results, it is advisable not to have the resistance between A and B either very large or very small as compared with the resistance of the battery. Thus, if we know that our battery has a resistance somewhere about 50 ohms (the measurement being taken, of course, to obtain its exact value), it would be preferable to use the 100 ohms shunt in preference to the one of 1000 ohms, or 10 ohms. Also we should have a resistance between D and E of, say 700 ohms, in preference to one of 7000 ohms: of course this latter adjustment will be considerably regulated by the power of the battery and the sensitiveness of the galvanometer. If we have no idea of what value the resistance of the battery is likely to be, the best plan is to use, say a 100 ohms shunt, and to make a measurement with that. Then if we find the result shows that the resistance of the battery is, say 900 ohms, substitute the 1000 ohms in the place of the 100 ohms, and make a fresh measurement which will give the resistance of the battery more accurately.

(To be continued).

Mr. **Streeter**, manufacturer of Electric Clocks and Machine made Jewellery and Watches, has removed to 18, New Bond Street.

PAPERS FOR JUNIOR STUDENTS.

Formulæ Analysed.—By **Arthur R. Granville.**

Many works of reference on matters relating to the science of electricity present a very uninviting appearance to students by reason of the large number of formulæ they contain—formulæ upon which the Telegraph Engineers' calculations are based when he has to localise a fault, or to predict its nature. Even in the simple periodic test for "conductivity" and "insulation," these expressions are brought into use.

It is therefore not only essential that students should acquire a knowledge of what formulæ are necessary to work out certain tests, but it is advisable that they should become familiar with their nature,—in other words, they should understand the rules upon which they are made into formulæ. The benefit to be derived from this class of study is that they become more fixedly impressed on the mind, and that an acquaintance with their nature stereotypes them on the memory ready for use in emergencies when books are not at hand to refer to.

The parts that "conductivity" and its converse "resistance" play in the calculations of all telegraph tests are so important that I commence this series of articles by the discussion of the following formula, viz., that which occurs in Mr. Clark's "Tables and Formulæ, p. 105:"—*The resistance, at 60° F., of any pure copper wire l inches in length, weighing n grains, equals* $\frac{0{\cdot}001516\, l^2}{n}$ *ohms;* and I propose to show that this resistance is identical with the other measurement of pure copper wire which, at 75° F., is quoted in the same chapter as equal to 1192·43 *ohms for a nautical mile weighing* 1 *lb.*

1.—The two measurements being at different temperatures, they must be reduced to the same.

2.—Divide the larger resistance by the number of inches in a nautical mile.

3.—Take the proportionate resistance of the inch piece of the nautical mile of copper wire, as compared with that of the piece weighing 1 grain, and the coefficient of the formula under consideration.

Commencing with (1), let us find the resistance of the mile length.

As metals improve in conductivity, and decrease in resistance, with a fall of temperature—

$$1192{\cdot}43\ (1-15t)$$

will equal the resistance at 60° F. of the mile length mentioned above, where t = the difference of resistance with each rise or fall of 1 degree. This quantity is mentioned by Mr. Clark to be 0·21 per cent, and a table of constants is given by him for various differences of temperature; but as it is better to be independent of tables, when possible, we may, by carrying on the calculation of which 0·21 is only a partial process, have a single *constant* which shall be useful for all practical purposes. This percentage is 0·00214 of an ohm, and is true enough for telegraph purposes. Now $(1-15t) = 0{\cdot}9679$, which, multiplied by 1192·43, the resistance R at 75° F., will give 1154·16 ohms, the closely approximate resistance at 60° F. of the mile of cable conductor weighing 1 lb. In this special instance we are, however, dealing with accurate measurements, and we must therefore make use of the exact resistance 1155·48, which experience proves to be the correct one.

To obtain (2) the resistance of one inch of such conductor, we merely divide 1155·48 by 73044, the number of inches in a mile, and we have 0·0158189 *of an ohm.*

This inch piece, however, only weighs $\frac{1}{73044}$ part of a lb., whereas a grain is $\frac{1}{7000}$ of a lb.; it follows, therefore, that the mass of the inch piece of the mile length is to the other inch piece as 7000 : 73044; so that the latter piece, weighing 1 grain, is $\frac{73044}{7000}$ times larger than the other. Hence, to obtain (3), we have again to divide the last quotient, namely 0·0158189, by $\frac{73044}{7000}$; because, although resistance is directly proportional to the length of the conductor, it is *inversely* proportional to its mass or weight. Finishing the calculation—

$$\frac{0{\cdot}0158}{\frac{73044}{7000}} = \frac{0{\cdot}0158 \times 7000}{73044}$$

we arrive at 0·001516 *of an ohm*, the constant of the formula $\frac{0{\cdot}001516\ l^2}{n}$.

That which now remains to be noticed is the symbol $\frac{l^2}{n}$. In conjunction with the constant 0·001516, it means that if the square of the length in inches of the conductor be divided by its total weight in grains, and the quotient multiplied by 0·001516, the result is the *total* resistance, whatever may be its length or weight. The expression $\frac{l^2}{n}$ may be resolved into $\frac{l}{\frac{n}{e}}$, of which the denominator $\frac{n}{e}$ is simply the proportion of the resistance of a mass of one inch conductor under test, as compared with that of a standard piece weighing one grain; and, therefore, $\frac{l^2}{n}$ mathematically signifies the length divided by that proportion.

It is thus very interesting to trace the connection between two different expressions for the same resistance of the same substance. These expressions are different in appearance and not in reality; for, if we wish we can measure the resistance of a thousand miles by the formula $\frac{0{\cdot}001516\ l^2}{n}$, though it should be remembered that we must first reduce the whole length to inches, and the whole weight to grains. Such a course would be too tedious for the practical engineer; and, therefore, whilst it is suited to the wants of scientists, who deal with absolute units and small quantities in their laboratory investigations, the larger quantity is convenient for telegraphists who require very large results.

Correspondence.

TELEGRAPH BENEVOLENT SOCIETY.

To the Editor of the Telegraphic Journal.

Sir,—Will you kindly allow me, through the medium of your valuable journal, to ask if there is now in existence a Benevolent Society in connection with the Postal and Telegraph Service, and, if so, the secretary's address, as I believe that something of the kind was started in London a year or two ago, though I have not recently heard of it. There are, doubtless, many besides myself to whom the information would be of interest now that the Post-Office seems to have finally fixed the sick allowance of the telegraph employés at the reduced rate of half-pay; but more especially, perhaps, will such information be appreciated by those who were formerly members of the Provident Clerks' Association, in which (owing to an arrangement between that Association and the Electric Telegraph Company) they could, by paying the required premium, insure up to two-thirds of their salary in sickness, besides a sum at death, but who, at the transfer, were compelled to forego the advantages of the sick allowance, a proportionate reduction being made in the premium to those who wished to continue the Life Assurance part of the policy. In a circular issued to the clerks by Mr. Linford, the secretary of the association, it appeared that such a proceeding had been rendered necessary through the Post-Office declining to carry out the Telegraph Co.'s arrangement, on the ground that the pay of the clerks was not stopped in sickness. For some time afterwards, indeed, it was not stopped, then it was reduced to two-thirds, and now to half-pay. This last downward move is one which those formerly connected with the Provident Clerks' Association have not yet been able to see the justice of, so far, at least, as it concerns themselves to whom the promises through Mr. Linford were held out, and in face of the general declarations made at the transfer that no one should suffer by the change. There is an exception in favour of some officials who are to continue to receive above half-pay; but as this regulation has not, so far as I am aware, been extended to those unfortunates who happened to join the Provident Clerks', instead of some other society unconnected with the Telegraph Co. (where they could, of course, have remained and received the benefit of sick pay), they are now reluctantly obliged, after paying into a society during several years, to seek out some other association, and pay an additional rate on account of increased age, as it is simply impossible that a sick man, either with or without a family, can exist in these times on Government half-pay alone, and find his own doctor; for it is only at large towns that a doctor is attached to the office.—I am, &c.,

A UNIT OF FORCE.

Proceedings of Societies.

ROYAL SOCIETY.

January 8, 1874.

"*On Electro-torsion*," by GEORGE GORE, F.R.S. This communication contains an account of a new phenomenon, of rods and wires of iron becoming twisted whilst under the influence of electric currents; and a full description of the conditions under which it occurs, the necessary apparatus, and the methods of using it.

The phenomenon of torsion thus produced is not a microscopic one, but may be made to exceed in some cases a twist of a quarter of a circle, the end of a suitable index moving through a space of 80 centimetres (=31 inches). It is always attended by emission of sound.

The torsions are produced by the combined influence of helical and axial electric currents, one current passing through a long copper-wire coil surrounding the bar or wire, and the other, in an axial direction, through the iron itself. The cause of them is the combined influence of magnetism in the ordinary longitudinal direction induced in the bar by the coil-current, and transverse magnetism induced in it by the axial one.

The torsions are remarkably symmetrical, and are as definitely related in direction to electric currents as magnetism itself. The chief law of them is—*A current flowing from a north to a south pole produces left-handed torsion, and a reverse one right-handed torsion*, i.e. in the direction of an ordinary screw. Although each current alone will produce its own magnetic effect, sound, and internal molecular movement, neither alone will twist the bar, unless the bar has been previously magnetised by the other. Successive coil-currents alone in opposite directions will not produce torsion, neither will successive and opposite axial ones.

The torsions are influenced by previous mechanical twist in the iron, by mechanical tension, and by terrestrial magnetic induction. The direction of them depends both upon that of the axial and the coil-currents, but appears to be determined most by the former. A few cases occur in which the currents, instead of developing torsion produce detorsion; but only two instances, out of many hundreds, have been met with in which torsion was produced in a direction opposite to that required by the law.

Single torsions vary in magnitude from 0·5 millim. to nearly 30 millims. of movement of the end of an index 47 centimetres long; the smaller ones occur when the two currents are transmitted alternately, and the large ones when they are passed simultaneously; the former generally leave the bar in a twisted state, the latter do not. Those produced by axial currents succeeding coil ones are nearly always much larger than those yielded by coil-currents succeeding axial ones, because the residual magnetism left by the coil-current is the strongest. The order of succession of the currents affects the torsions in all cases, altering their magnitudes, and in some few instances even their directions. In steel all the torsional effects are modified by the mechanical and magnetic properties of that substance.

Each current leaves a residuary magnetic effect in the bar, amounting in iron to about one-tenth of its original influence. The residuary magnetism of coil-currents is affected and sometimes reversed by axial ones, and that of axial currents is also removed by coil ones, and by a red heat. The condition left by an axial current is smaller in degree, and less stable in a vertical iron wire, or one in the terrestrial magnetic meridian, than that left by a coil one, partly because of the influence of terrestrial magnetism, but in a position at right angles to that the effect is different.

The torsion produced by a coil-current may be used as a test, and partly as a measure of the residuary effect of an axial one; and that produced by an axial current may be employed to detect, and to some extent measure, ordinary magnetism in the bar. As an opposite coil-current at once reverses the ordinary longitudinal magnetism of a bar of iron, so also an opposite axial one at once reverses its transverse magnetism.

Many instances have been met with in which the transverse and longitudinal magnetic states produced by the two currents coexisted in the same substance. The torsional influence of the excited helix is distributed equally throughout its length; so also is that of the current in the bar. All the torsions are closely related to the well-known electric sounds, and to particular positions and internal movements of the particles of the iron.

Signs of electro-torsion were obtained with a bar of nickel, but not with wires of platinum, silver, copper, lead, tin, cadmium, zinc, magnesium, aluminium, brass, or German-silver, nor with a thick rod of zinc, or a cord of gutta-percha.

SOCIETY OF TELEGRAPH ENGINEERS.

THE ordinary general meeting of this Society was held on Wednesday evening. The President, Sir William Thomson, in the chair. After the transaction of the preliminary business, The **President** said the first subject on the agenda was the adjourned discussion on "*Underground Telegraphs.*"

Major **Webber** said the very interesting paper read at a previous meeting by Mr. George Preece gave a most complete account of probably the most perfect underground telegraph line that had ever been laid down in this country, but he said very little of the history of the past maintenance of underground telegraphs and the experience of those connected with their construction. He (Major Webber) then ventured to remark that the history of underground telegraphs, so far as they knew, was not such as to make it desirable to perpetuate the use of covered wires carried underground; but he only did so in order that perhaps others who had had experience of it in other countries would tell them something about it. Seeing that the paper for the evening was likely to be of so much greater interest to the meeting than anything he was likely to say on the subject of underground telegraphs, he would not take up their time, but hoped that the subject would be again brought forward on some future occasion.

Mr. R. S. **Culley** said the great difficulty with underground telegraphs, so far as he knew, had been in the joints. Mr. Preece took especial care with his joints, and they appeared to stand very well indeed; but it was almost impossible to afford the time that was necessary to make the joints in the perfect manner that Mr. Preece had done. There were 250 or 280 gutta-percha wires running through the Holborn viaduct, and 280 wires jointed on Mr. Preece's system would take very likely 280 half days to complete. They were consequently obliged to use a much rougher mode of making the joints, which, in competent hands, was generally fairly successful. But still, though they tried to teach the men to joint, they found that their wires were constantly giving more or less trouble at the joints, not so much in London as in the country. In London the joints stood tolerably well, because they had men who had been making joints, some of them, for these 20 years. If any one could invent a method of jointing gutta-percha wire that could be done more quickly than the kneading method, and yet would give a fair joint that would stand, and a fair amount of insulation, say ten millions, it would be a very great advantage.

Mr. **Trueman** said he believed he was in a position to say that such a joint could be made,—a joint of perfectly solid gutta-percha, without any appreciable loss of insulation,—and that such a joint could be made in the course of perhaps 20 minutes. He had some experience in the use of gutta-percha, and for many years it had been his hobby to use all the knowledge he had for the purpose of advancing its use for telegraph purposes, one of his main objects being to improve the joint. The great impediment in the way of a perfect joint was the compound, for they could not manipulate the gutta-percha properly when they had another substance intervening between the layers. He believed that a solid gutta-percha covering without any compound was what they wanted, and at some future period he should be happy to lay before the Society any knowledge he might have upon the subject.

Mr. R. S. **Culley** read a paper on "*Duplex Telegraphy.*" He stated that the details of the system are too minute to be dealt with successfully in a paper before an audience. The first questions which are asked are, How do the currents pass one another in line wire? and if they do pass, how is it they do not interfere one with the other? Telegraphists are too well aware that when two stations dispute for the possession of a circuit, the signals of each station are affected by those of the other, and neither station can read a word. In the case of the single needle, it is found that when the direction of the two currents is the same, the needle moves more strongly than when the current is simply from its own battery; and when the direction of the two currents differs, the needle scarcely moves at all. As the effect of this is entire confusion of signals, they must see whether it would not be posible to unravel this confusion, and if so, they would resolve the problem of the duplex. Suppose, first, that each sending-clerk knows the force with which his needle ought to strike the stops by the action of his own current, so that it is just possible for him to see when the distant station, B, sends a current in the same direction as he is doing at A, because at that moment A's needle strikes the stops more strongly than usual. Let A read that movement as a signal sent by B in the same direction as his own. Secondly, if B tries to move A's needle in the opposite direction, it will strike the stops less strongly, or perhaps will only move half-way to the stops. Let A read this as a movement in the opposite direction to his own. If it were possible, then, to have two clerks, one standing by the key and watching the way the sender moved his hand, and at the same time watching the movement of the needle and the strength of the deflection, it would be possible for him to know what signal the distant station sent. The author does not mean to say that, practically, anyone could read in this way, but it is just possible the direction of signals sent by the distant station might be distinguished. Thus it would be seen that, if by any means they could arrange so that a station's outgoing current could not affect his own needle, it would leave his dial free to show only the effect produced by the incoming current, and then the signals sent by the two stations would be separate one from the other. How then can each instrument be so connected that another sender shall affect his own needle, and yet so that his coil shall always remain in circuit to receive the current of the distant station? The author proceeds in his paper to consider what occurs in testing a line wire simultaneously between two stations for resistance with a differential galvanometer. He shows by actual experiment that so long as the resistance of the rheostat at each end remains equal to that of the circuit tested, each station will see the current sent by the other, although neither of them can see his own current. The reason is this; the current sent by each station is divided equally between the line wire and the rheostat. The two resistances being equal, the currents in the two coils are equal, and, therefore, the outgoing current does not move the sending station signal. The two currents do not pass one another as has been imagined; but when both stations signal at the same time, the current sent by either station acts upon the distant instrument by determining, for the moment, whether the line or the rheostat shall offer the easier path for the current originating there. In studying the effects produced by the varying positions of the key at each end of the circuit, the author states that it is better to take the case of a single instrument working by a single current, such as a Sanger or a Morse. In working one of these instruments the batteries are generally connected, so that when both keys are pressed at the same time, the currents flow in the same direction and assist one another, and when either station signals separately the currents are divided. But if the distant station depresses his key, he puts a zinc current on the line that assists the current in the line, but does not assist the current in the rheostat; therefore the strength of the current in the line is much greater, perhaps double that in the rheostat, and the needle of the distant instrument moves because the resistance of the line is virtually decreased, or the effect is the same as that of decreasing the resistance of the line. In the case of the single needle, if A sends a positive current, while B sends a negative current, the two are in the same direction, and both needles move alike. The rheostat of course is not affected in any way by the two currents, but has an independent circuit of its own. But when both stations send positive currents to line, the two currents oppose one another; and if two batteries are connected in that way, no signal can be sent. But if B puts down his key, he opposes the current; no current passes to line; it all goes the back way, and the needle obeys the rheostat. The author then proceeds to enquire whether the law of difference of potentials can be applied to explain this point, answering this question affirmatively. The duplex principle is applied to the needle instrument by winding the coils differentially, and it can be applied to the Sanger or the Morse by winding the relay or the magnet differentially when the magnetism produced by one coil counteracts the other, and equal currents pass through the two, or without altering the electro-magnet, the wire can be connected to the short branch which connects one bar of the electro-magnet to the other bar, so as to split the current. Then, one power of the electro-magnet will draw the needle down, and the other repel it, and thus a balance is obtained. This arrangement answers very fairly for short lines, and can be also applied fo a polarised relay; but it is subject to grave inconvenience when used on longer circuits. Instead of re-winding the coils and arranging them differentially, they can be placed in the Wheatstone bridge, in the position in which the galvanometer of a Wheatstone bridge is placed during testing. The *rationale* of this arrangement is precisely similar to that of the differential; neither instrument is affected by outgoing currents so long as the resistance of the line and of the rheostat are equal, but if anything occurs to alter the resistance of the line, the instrument is affected precisely as if it were the galvanometer used for testing the resistance. When the stations work singly, a portion of the current passes from the line through the galvanometer direct to earth, through the rheostat; another portion passes by the other branch of the bridge; in fact, the two wires of the bridge are a shunt, as it were, on the galvanometer. With the bridge arrangement, the ordinary apparatus, whatever it may be, can be used without alteration. It need not be re-wound, but, as far as our experience goes at present, the differential method is preferable, in difficult cases especially. When the circuit exceeds 100 miles, or contains cable or underground wires, it is found, especially in very dry weather, that, however perfectly the resistances are adjusted, the balance is disturbed by the key making or breaking the contact. This is due to the static discharge from the line, and must be counteracted by making the capacity of the artificial line, the rear stud, equal to that of the actual line. This is done by means of condensers, and the introduction of the condenser is really the most important point in Stearns' improvement. When the cable exceeds a few miles in length, its charge and discharge occupy a longer time than is required for the discharge of the condenser, and it is necessary to retard the action of the condenser. The more evenly the induction is distributed over the artificial line formed by the condensers and resistance-coils, the more perfect is the compensation. As the artificial line forms a derived circuit for the battery-current, the resistance of the battery must be very low, and as a rule the number of cells is greater than for a single current. The rear stud, of course, has to be made adjustable to balance the varying resistances of the line, as line wires vary 50 per cent in a day in resistance in bad weather. The capacity of the condenser must also be made variable. As it is necessary, again, that the resistance of the circuit shall be uniform at all times, an arrangement is required in the key to compensate for the resistance of the battery when the battery contact is open; for if this is not attended to, the circuit for the in-coming current, when the key is down and the battery in circuit, is divided, but when the key is up, the circuit is through the rear stud only. A resistance equal to that of the battery is therefore placed between the back stop of the key and the earth; therefore, whether the key is up or down, the resistances are equal. This compensation hardly appears to be absolutely necessary for short circuits, especially if the play of the key is small. The author concluded by stating that it was hardly necessary to go further into detail, but he would be glad to answer any questions which might be put to him.

Mr. Latimer Clark said he had listened with much interest to the paper, but had been surprised to find no mention of the history of the subject. It was only right to state that the duplex system was very well known in this country as long ago as 1853, and experiments were made upon it by the Electric Telegraph Company, and it was found to work tolerably well. But at that period the amount of business was not sufficient to render any acceleration of messages necessary, and therefore the system fell into disuse. About that period, Dr. Siemens made considerable improvements on the system, and no doubt if there had been the same demand for quick transmission as there was at the present day, the system would then have come into practical operation and use. It was, however, laid aside as a scientific telegraphic curiosity until it was recently revived in America, and Mr. Stearns appeared to have taken it up, and introduced it in America and in this country, and to Mr. Stearns was due the very great merit of having added to the system the use of condensers. As the system was known in its incipient stage, they only thought of balancing the resistance of the line and the batteries, but did not proceed far enough to discover that there was any such thing as interference by means of the electric induction of the line. Mr. Stearns had advanced beyond them, had observed the effect of induction on the lines, and had also shown them how to counteract it. It was only fair to state that some of the officers of the Eastern Telegraph Company had quite independently, and at about the same period as Mr. Stearns endeavoured to apply the duplex system to submarine lines, and of course they at once met with the difficulty of induction. They commenced experiments with the same object as Mr. Stearns, namely, to balance the induction of the line by the use of condensers. He need scarcely say the system was a very important one, and it was one that had already come to be adopted very extensively in this country. It was very extensively adopted in America, and would very soon become universally used throughout the world not only for land lines, but for submarine lines,—for the experience of the officers of the Eastern Telegraph Company showed that it could be practically applied to submarine circuits. The result was that it not merely doubled the power of the line, but that practically it more than doubled its sending power.

Mr. Culley said that the duplex system might be used in all weathers up to 200 miles, but sometimes the weather was so bad that it was difficult to work the 400 miles circuit. Probably before another year was over they would have overcome that difficulty.

The President said he had listened with great interest to the account which Mr. Culley had given of the successful re-introduction of the duplex system. Mr. Stearns' method contained one important addition to any method which had been previously used for working on the duplex system. Mr. Culley had explained the introduction of the condenser, and it was this that had rendered the duplex system practicable in the more considerable lengths upon which it had recently been successfully tried. So far as the general principle of the condenser was concerned, it was the development of a method that had long been known for duplex working through the submarine telegraph, and which consisted in the application of a complete model of the submarine cable in connection with the resistance at the sending end. The conditions which had been explained by Mr. Culley required that when the operator pressed his key, precisely the same effect should be produced in the secondary or adjustment line as was produced in the main line,—that precisely the same current should run from the key through the receiving instrument into the secondary line and into the primary line to make sure that not only should the whole amount of the current be the same, but that it should commence at the same moment, rise with the same rate of augmentation, and come to nothing again at the same rate. When he said that equality was necessary, he ought to correct the statement and say that proportionality would suffice, but equality was the most convenient system. Some of the old methods consisted in keeping proportional currents, currents which, though not equal in the two branches, should bear a definite proportion, and the same remark applied to the introduction of an artificial submarine line in the adjustment arrangement. The idea of getting a perfect balance by aid of Mr. Varley's artificial line had been long well known. With reference to the successful duplex telegraphing of submarine lines, this had been realised for the first time through a considerable extent of line by Mr. De Sorté, on the line between Malta, Gibraltar, and Lisbon, and the result certainly was very striking and interesting. Those members who had seen an account of this experiment in the Journal would recognise the more complete working out of the thing which was there described, and which was essential for giving a successful duplex action in the submarine cable. The varying insulation of land lines made it very difficult to keep the adjustment correct, to change it quickly enough, or to allow the action to go on, notwithstanding these great variations of insulation; and in submarine lines the balance required was very much finer than anything required for the land lines. The difference between the strength of the current going into the line from the sender's instrument, and the exceedingly attenuated changes of strength of current by which alone the messages were read off in long submarine lines, presented circumstances of very great difficulty, so far as rendering the duplex working possible. It was, he considered, greatly to the credit of the operators on the eastern line that they succeeded so well as they had done in the experiments that had been referred to. Whether any amount of adjustment could be practically perfect enough to carry out the duplex system, on the longer submarine lines worked at high speed, was a question that could only be answered by actual experiment. The theory was obvious, the experimental realisation of it was very difficult. Even so comparatively short a line as that between Lisbon and Gibraltar had taxed very much the great skill, perseverance, and patience of Mr. De Sorté and his colleagues. It certainly was a most interesting point, and he hoped they would not flag in their efforts, but would find out how much could be done on the longer line. If a submarine line was only worked slow enough, then its signals were precisely those of a very perfectly insulated land line; therefore, whatever could be done upon a land line could be done with even greater sureness on a submarine line, if the speed were not an object. But as the whole object was really to increase the speed of the line, of course, if the speed necessary to carry out such an adjustment was considerably less than half that which could be obtained without it, then the method would not be practically valuable. If, on the other hand, the adjustment could be made successfully for a submarine line of great length, working at something more than half the speed at which it could be usefully worked on the single system, then the duplex system would be useful. He begged to return the thanks of the Society to Mr. Culley for his interesting and valuable communication.

The thanks of the Society were accorded to Mr. Culley, and also to Mr. Preece for his paper on "Underground Telegraphs."

The Society then adjourned.

Electrical Science in Foreign Journals.

Comptes Rendus Hebdomadaires des Séances de l'Academie des Sciences, Vol. lxxviii., No. 1.

On the Conductibility of Magnetic Tensions.—M. Jamin.—Reserved for separate note.

On the Variable State at Closure of the Voltaic Circuit.—M. Cazin.—(Reply to M. Blaserna.)

No. 2.

Chemical Dynamics; Intervention of Water in Chemical Combinations; Electrodes of Water and other Liquids, and their Properties.—M. Becquerel.—(Extract from third memoir.)—In mixture of two solutions, electromotive forces are always produced, some arising from hydratations, others from combinations. They may be distinguished and measured by means of water electrodes. The arrangement is this: Take a vessel containing acid solution, and place in it a cracked tube containing alkaline solution. In each of the solutions put a cracked tube filled with distilled water, in which is a gold or platinum plate perfectly depolarised. Before combination, and during the very short time in which it takes place, the acid forms a new hydrate with the water of the alkaline solution, and conversely; and two electric currents are produced, one from hydratations, the other from combination of the acid with the alkali. Now, water electrodes being used, there are two currents, due to hydratation, which have an inverse direction to the two first, produced during combination, and neutralise them, so that there remains only the current due to electromotive force resulting from the combination of acid with alkali. Several applications of this principle are described. The method serves for comparing the affinities of substances in solution by separating the two kinds of electrical effects, and in such a way that it is not necessary to introduce gold or platinum electrodes into the solutions, which sometimes attack the metal, and may thus lead to error.

On the Distribution of Magnetism in Soft Iron.—M. Jamin.—The author experimented with a bar of square section, 2 metres in length, and 20 mm. width; the two extremities being surrounded by two bobbins, traversed by a current from 20 Bunsen elements. He sums up as follows: (1.) When the two currents are parallel, the intensities produced by each of them are restrained (*se retranchent*); they are augmented, when the currents are opposed. (2.) In the former case, the sum of magnetisation developed is less; in the latter it is greater. (3.) If the theory of solenoids were admitted, the action of parallel currents should be accumulative, and the sum of intensities should be increased; it is the opposite that occurs. (4.) When the currents of the bobbins are in opposite directions, they should act inversely on the particular currents of iron, and the effects be reduced; they increase, on the contrary. (5.) The action of the bobbins should be *nil* at the middle; this is not the case. The author thinks these phenomena should lead to modifications in the theory of solenoids.

Les Mondes. Vol. xxxiii., No. 3.

This number contains no original papers on electricity.

No. 4.

Economic, Portable Batteries with Constant Continuous Current (Illustrated).—M. Trouvé.—The apparatus contains 40 or 80 elements, and its volume does not exceed 2 or 3 cubic decimetres. Each of the elements is composed thus: between two discs, one of copper, the other of zinc, are placed a number of round pieces of blotting paper; one half of the rouleau has been saturated with sulphate of copper, the other half with sulphate of zinc. The elements are arranged for tension, in a case of hardened caoutchouc, and about a commutator and galvanometer; the whole being enclosed in a mahogany box. When the apparatus is to be used, the elements are simply all immersed at once in ordinary water, which, absorbed by the paper, dissolves the sulphate of copper and sulphate of zinc, producing the chemical action necessary to a current. The paper remains moist a long time. To re-charge the pile, it is sufficient to immerse it one-half in sulphate of copper solution (since the sulphate of zinc is continually being produced). Thus the battery is very economical, and suitable for specialists, or medical men, who may only use a battery at long intervals. The mode of using it is fully detailed.

Der Naturforscher. November, 1873.

The Internal Mechanics of Nerves.—M. Bernstein.—The author supplements Pflüger's observations on the phenomena of electro-tonus, and makes some suggestions towards an explanation of them.

Poggendorff's Annalen der Physik und Chemie. No. 9.

Contributions to a Better Knowledge of Electric Machines of the Second Kind.—M. Poggendorff.—The machines referred to are those with two discs rotating in opposite directions; as distinguished from machines of the first kind, with one rotating and one stationary disc. They are especially interesting from the theoretical point of view; and their mode of action is here examined. Supposing the machine to be excited by induction (a negatively electrified ebonite plate being held opposite the metallic comb), and the discs put in rotation. M. Poggendorff considers (in opposition to the common view), that there is not a suction (*Einsaugung*) by the conductors of the electricities expanded on the insulators; but that, on the contrary, the electricities separated by induction in the conductors stream over to the insulators. Thus both modes of excitation, through induction and through inflow, are explained on one principle, which is alike applicable to both kinds of machines.

On a New Tangent Galvanometer and a Rheocord.—Dr. Friedrich Müller.—Ordinary rheostats are too inaccurate, and are only available for small intensities; and in the ordinary tangent galvanometer, the sensibility diminishes with the angle, and the reading wastes time. These faults Dr. Müller sought to remedy; the galvanometer needle is deadened by being immersed in glycerine diluted with $\frac{1}{8}$ of water; above and in rigid connexion with it, is a horizontal fine glass tube, from either end of which proceeds a platinum wire bent upwards, so that the two wires are in one plane with the suspending thread. A scale is looked at beyond and along this (imaginary) plane; the motion of the needle, of course, producing divergence in the platinum wires. The wires of the rheostat are kept cool by distilled water.

Bulletin de l'Academie Royale de Belgique.
Nos. 9 and 10.

On the Electrical Phenomena of the Heart.—Dr. Nuel.—Distinguish between the phenomena *during repose*, and those *during contraction.* During (the interval of) repose, the heart being fresh, intact, and beating regularly, a small current (0·001 D) may be observed, on applying electrodes, from the apex to the lateral face, increasing with the distance between the points. If the heart is exposed to air, however, this diminishes rapidly, and is reversed in less than 10 minutes. (This change was not before observed). Any wounded point is negative to every other point of the surface. The circuit being closed between a point of the intact surface and the transverse section, a considerable current (0·08 D) flows from the former to the latter. This diminishes, at first quickly, then slowly; but is found to be increased, after a contraction of the heart has been produced. As to the phenomena *during contraction*, the weak current of the surface of the intact and fresh heart does not change; but if by lesion a strong current is had, this is weakened, and even reversed during systole. The negative variation precedes contraction; it seems to reach a maximum at the commencement of systole, and lasts till the end of the contraction. The experiments were mostly made on the hearts of frogs.

Note on a System of Universal Meteorography.—M. Van Rysselberghe.—An ingenious arrangement (involving use of electrical apparatus), not easily described without the accompanying figures. This meteorograph has been now for several months in use at Ostend; it registers at once barometric, thermometric, and anemometric observations; and the author proposes also to include hygrometric and magnetic.

Revue Scientifique de la France et de l'Etranger. No. 28.

On Electricity Liberated by the Passage of a Liquid Current in a Tube.—M. Hoorweg (to the Amsterdam Society of Natural Sciences).—Repeating M. Zöllner's experiments, the author found that if the platinum plates were placed at two points of a water current traversing a glass tube, and were connected by a conducting wire passing through a sensitive galvanometer, no electric current was obtained, if the jet of water issuing from the tube were received into a glass vessel; but that a current appeared whenever one touched the water jet with the hand or some conductor. If, however, there occur between the two plates of platinum a contraction of the tube, an electric current appears, even when the water jet is insulated. This, which has the same direction as the water current, M. Hoorweg considers of the same nature as the currents caused by diaphragms, studied by M. Quincke.

Journal Telegraphique, Vol. ii., No. 22.

Telegraphy at the Vienna Exhibition.—This paper (first of a series), gives a general survey of the exhibits from the various countries.

Electric Pantograph.—M. Hasler.—The design of this ingenious instrument is to transmit figures, drawings, &c., by telegraph, in a way analogous to that of the ordinary pantograph with parallelogram lever. A style, with pencil, at receiving station B, is so arranged as to make, simultaneously, the same movements as a style at sending station A. Suppose the style at A moved right or left, back or forwards, over the figure. It makes by its motion a number of successive electrical contacts, through which currents caused to act on electro-magnets at B (and there is a separate line and electro-magnet for each of the four opposite directions (say), *a*, *b*, *c*, *d*, in which the style at A is moved). The contacts are made thus: from the style at A, pass cords, with attached weights, over two horizontal cylinders at right angles to each other, on the axis of which are toothed wheels, against which, as they rotate, a spring presses; thus are transmitted a number of successive currents, proportional to the space passed over by the style. Suppose the style at station A moved obliquely, in a line which is the resultant of two co-ordinates, *a* and *b*. Then the two electro-magnets at the receiving station, corresponding to *a* and *b*, act simultaneously and move the style there in the same direction as the resultant. The style then describes a broken line, which approaches nearer to a straight line the more numerous the contacts. The oscillatory movement of the receiving electro-magnets is changed into a rotatory one, which directs the style of the apparatus.

American Journal of Science and Arts, Dec., 1873.

On the Magnetic Permeability (or Conductivity), and the Maximum of Magnetism of Iron, Steel, and Nickel.—By Henry A. Rowland, C.E.—In all mathematical theories of induced magnetisation, a quantity is introduced depending on the magnetic properties of the substance; and it has been treated as constant, but is shown by Mr. Rowland to vary widely. He deduced the constant from experimental data for twelve kinds of iron and two of nickel. He also obtained the maximum value of Q (or magnetic field in interior of bar), and found it for good, but not pure iron, to be about 175,000, and for nickel 13,000; "that is, the magnetisation of iron can never exceed 175,000 times the unit magnetic field, on the meter, gramme, second, system, neither can nickel exceed 63,000 times . . . We can also deduce from these quantities" (and with aid of a formula given by Maxwell), "the greatest weight which an electro-magnet can sustain." This, with infinite current, is found to be for iron 354 lbs. per square inch of section, and for nickel 46 lbs. These results are confirmed by experiment.

Signalling in Mines by Electricity.—At a meeting of the North Staffordshire Institute of Mining and Mechanical Engineers, held at Stoke-upon-Trent, on the 5th inst., Mr. T. M. Goddard read a paper on "Better Communication in Pit-Signalling by means of Electricity." It was essential to the successful working of the system that the wires should be well insulated to prevent breakages. This system required less room than the old one in shafts; and the wires required no play, as did the old stranded bell wire. However much the wire was coiled, contact remained perfect, independent of distance, thus avoiding the necessity for laying wires in upcast shafts, where the effects on wire were so detrimental. By this system the noisy clapper was done away with, except in shaft repairs. Enginetenters were not so liable to make mistakes with the new as with the old method. He showed that it was a great advantage to avoid the upcast for signalling, as they might by the new system. Where cages were working in wooden conductors in shafts of small area, there was no danger of the cage tearing the wire from the staples, and cutting off communication between hooker-on and engine-tenter. Where minerals were got below the downcast, wires could be conducted down, and signals communicated as effectually as if they were sent direct up the upcast, showing this system was peculiarly applicable where ventilation by fan was not in use. He pointed out the new system was more economical, and more easily maintained; and urged that it was more efficient than the old system. Several members expressed themselves favourable to the new system, and it was decided that Mr. Goddard's paper should be printed.

The success of the Christmas programme of the Polytechnic will defer for a short time the production of a lecture by Dr. Croft, the managing director, upon 'Safety in Railway Travelling."

City and Commercial Notes.

Amongst the new companies "registered" since our last issue is The British Telegraph Manufactory, Limited. Capital £30,000 in £10 shares.—According to the specification, this Company will acquire, in addition to the business carried on under the name of the British Telegraph Manufactory, "the following Letters Patent, or any rights or interests therein, granted to or owned wholly or partially by Sir Charles Wheatstone, for the purposes following, that is to say:—"Improvements in Electro-Magnetic Telegraphs, and in apparatus connected therewith, parts of which improvements are applicable to other purposes." "Improvements in Electric Telegraphs and in apparatus connected therewith." "Improvements in Electro-Magnetic Clocks, parts of which improvements are applicable to mechanical clocks." "Improvements in Electro-Magnetic Telegraphs and apparatus for transmitting signs or indications to distant places by means of electricity, and in the means of and apparatus for establishing electric telegraph communication between distant places." "And any improvements thereof, and any other Letters Patent, now or hereafter belonging to, the said Sir Charles Wheatstone, or any licences, shares, rights, or interests under such Letters Patent. The Company will also acquire any other patents heretofore, or which may hereafter be granted to any persons for any inventions in electricity, magnetism, or telegraphy, or connected therewith." The subscribers who take ten shares each are: Sir Charles Wheatstone, 19, Park-crescent, Regent's-Park; R. Sabine, 172, Great Portland-street; H. Kimber, 79, Lombard-street; F. Braby, Mount Henley, Sydenham; Sir S. Canning, 7, Great Winchester street-buildings; T. H. Puleston, 41, Lombard-street; and W. Abbott, 10, Tokenhouse-yard.

Those shareholders of the West India and Panama Telegraph Company (Limited) who were chosen by their co-partners to be directors of the Company, in the place of the old directors (who resigned at the recent meeting), were formally elected at the adjourned meeting on Wednesday the 21st ult., the Chairman was able to communicate to the meeting the satisfactory intelligence of the buoying of the shore end of the Porto Rico Jamaica Cable off Porto Rico.

TELEGRAPH SHARE LIST.

Amount per Share.	Name of Company.	Amount paid up.	Closing Quotations.
£		£	Jan. 30.
Stock	Anglo-American (Limited)	100	79—79½
10	Brazilian Submarine..	9	3½—3 dis.
10	Cuba	All	7½—8
10	Direct Spanish	9	1 dis.—par
20	Direct United States Cable	17	8—6 dis.
10	Eastern (Limited)	All	7⅝—7⅞
10	Do., New	..	..—..
10	Eastern Extn. Australia and China	All	7⅝—7⅞
10	Globe Telegraph and Trust	All	7⅛—7⅜
10	Do., 6 per cent Pref...	All	9⅛—9⅜
10	Great Northern	All	9¾—10¼
25	Indo-European	All	15½—16½
10	Mediterranean Extension (Limited)	All	4—4½
10	Do., 8 per cent Pref...	All	11½—12½
10	Panama and South Pacific	2½	..—.. dis.
8	Reuter's..	All	11—11½
Stock	Submarine	100	235—245
1	Do., Scrip	All	2¼—2½
10	West India and Panama	All	5½—5¾
10	Do., 10 per cent Pref.	All	9¾—10¼
20	Western and Brazilian (Limited) ..	All	12½—13½
1000 dls.	West Un. U.S. 7 per cent 1st M.B.	All	101—103
10	Hooper's Telegraph Works	All	13—13½
50	India-Rubber and Gutta Percha ..	All	29—31
Cert.	Submarine Cables Trust	100	107—109
12	Telegraph Construction	All	32—32½
100	Ditto Ditto 7 per cent Bonds	All	100—103